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AUTHOR Char, Cynthia
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ABSTRACT

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Computer Graphic Feltboards:
New Software Approaches to Children's Mathematical Exploration

Cynthia Char

Report No. 91-1

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Computer Graphic Feltboards:

New Software Approaches to Children's Mathematical Exploration

Cynthia Char

This paper presents a research study of children using on-screen manipulatives (objects represented graphically on the computer screen) in learning mathematics. The paper begins by offering the rationale for the use of manipulatives in mathematics education, an assessment of why manipulatives are not more commonly used in schools, and a discussion of the potential benefits of on-screen computer manipulatives. It then discusses a program of research in which sixty-three kindergarten and first-grade children used software to construct "computer beansticks" as part of a series of classroom activities focused on number patterns, grouping, and addition. Among the results was the finding that the open-ended nature of the software offered children an environment for independent and collaborative exploration and expression, and provided teachers with a tool for class presentations and informal assessment.

Young children, by the age of five, already possess considerable experience and growing facility with various types of symbolic activities. Using spoken words, gestures, and materials such as crayons, wooden blocks, and toys, they are able to represent objects, actions and events, ideas and feelings (Gardner 1983; Gardner & Wolf 1979; Smith 1983). Throughout the preschool years, there is a "genuine flowering of symbolic capacities" (Sheingold 1986), evidenced in the emergence of a variety of "symbolic products": stories, songs, dance, drawings, dramatized narratives, and elaborate block constructions.

Then, between the ages of five and seven—during the early primary school years—children begin learning more formal notational symbol systems. Much of early elementary school is focused on introducing children to written language through

reading and writing assignments, and to mathematical notation. As Resnick (1987) notes, "Outside school, actions are intimately connected with objects and events. . . . School learning, by contrast, is mostly symbol-based; indeed, connections to the events and objects symbolized are often lost. . . . School learning then becomes a matter of learning symbol manipulation rules and saying or writing things according to the rules."

This disjuncture between symbols, objects, and events poses a particularly acute problem in the area of mathematics learning. According to Gardner (1983),

> [The origins of mathematical thought] can be traced to a confrontation with the world of objects. For it is in confronting objects, in ordering and reordering them, and in assessing their quantity, that the young child gains his or her initial and most fundamental knowledge about the logical-mathematical realm. (p. 129)

Manipulatives in Elementary Mathematic Education

Following this line of reasoning, the use of manipulatives—physical objects with which mathematical constructs can be modeled—is widely recommended in elementary mathematics education. As Campbell (1988) states, "It is necessary for children to reflect on, and to verbalize their perception of, the mathematics embodied in hands-on materials, and for teachers to help students make the critical connection between materials and symbols."

When used well, manipulatives serve several educational purposes:

- They provide concrete embodiments of mathematical concepts and processes that young children can understand and internalize. These internalized models provide a strong basis for later mastery of more abstract symbolic representations of the mathematical concepts and processes (Dienes 1966; Resnick & Ford 1981).
- They provide tools for children to use in solving problems. These tools can help introduce childen to mathematical problem solving, and they provide a means of support as children learn and practice more sophisticated approaches to solving problems (Wirtz 1974).
- They provide vehicles that facilitate communication about mathematics. Teachers can use manipulatives to physically demonstrate processes, point out visible patterns, and direct children's attention. Childen can use manipulatives to demonstrate how they solve problems, thereby helping the teacher assess students' understandings and misconceptions (Baratta-Lorton 1976).

Well-designed manipulatives are readily available. Suppliers of educational materials provide a myriad of manipulatives designed for elementary mathematics, as well as books for teachers about activities using manipulatives. Attribute Blocks, Pattern Blocks, Tangrams, Geoboards, Unifix Cubes, Base-Ten Blocks, Cuisenaire Rods, and Dienes Blocks are among the most widely known, and sets of these are available in many schools. Common objects that students and teachers can collect—including beads, buttons, keys, and beans—can also provide useful manipulatives (Baratta-Lorton 1972).

Despite their known potential value and widespread availability, manipulatives receive little use, or ineffective use, in most classrooms (Cohen 1990; Fey 1979; Peterson 1990; Suydam 1987). Several difficulties account for this.

Classroom management. Distributing, collecting, and reorganizing manipulatives can be time consuming, as can searching the classroom for missing pieces. Some students are tempted to play disruptive games with the materials.

Structuring, monitoring, and assessing the use of manipulatives. Providing each child with appropriate goals, help, and feedback, and assessing what each child is doing and learning, can be difficult in a typical classroom of twenty or more students.

Relating manipulatives to mathematical symbols and procedures. Children can be successful at carrying out processes with manipulatives, while failing to relate their experiences with manipulatives to mathematical symbols and operations (Baroody 1989). For example, several researchers (Ginsburg 1977; Wirtz 1974) have reported observations of children who did

not realize that they should obtain the same answer when they add two numbers by using manipulatives as when they add the same two numbers by using a written addition algorithm. The difficulty of building bridges between manipulatives and symbols, combined with strong school and parent expectations that children will learn to add and subtract written numbers, leads many teachers to bypass using manipulatives and spend the available time having students learn and practice the basic facts and algorithms. Frequently, the result is rote learning without conceptual understanding.

With the entry of the microcomputer into this already complex world of the elementary mathematics classroom, to what extent is it possible to capitalize upon the computer's ability to present pictures, numbers, words, sound, and movement to serve as a bridge between manipulatives and numerical symbols? Can computer graphics software offer a valuable form of experience with manipulatives for young children engaged in mathematical exploration?

The Potential of On-screen Manipulatives

On-screen manipulatives—computer graphic images that students and teachers can manipulate—may have the potential to provide the educational benefits of physical manipulatives in more manageable forms; overcome the disadvantages of traditional manipulatives; and provide additional, educationally valuable functions. The potential advantages of on-screen manipulatives include the following:

- Reducing classroom management difficulties, since on-screen manipulatives do not need to be distributed, collected, or reorganized, and individual pieces cannot be lost.
- Reducing the difficulties of structuring, monitoring, and assessing students' work with manipulatives by exploiting the software's capabilities to specify goals, provide hints and feedback for students, and provide automatic record keeping for teachers.
- Helping students build cognitive linkages among different representations of mathematical constructs. With software that provides *linked representations*, students can manipulate one representation while the computer makes corresponding changes in another. For example, a child could drag a set of coins onto the screen, and then click on a mouth icon to both hear in digitized speech and see in written notation the total value of the coin set.[1]
- Providing clearer models of mathematical constructs. Various visual techniques can be used to provide good models, such as animation to show mathematical transformations—for example, to demonstrate the regrouping of objects in a set, or to illustrate the "take away" model of subtraction.
- Encouraging students' collaborative work. Forman (1984) observed that when a small group of students worked at a computer, with one student controlling the input device, they engaged in more planning, discussion, and debate than when they worked with actual objects.
- Enabling review of students' work through the use of the software's "record and replay" capability. When students work with physical manipulatives, their activities go unrecorded. With computer manipulatives, each manipulation can be recorded and later replayed. These record and replay capabilities can encourage students to review and reflect upon what they have done (Forman 1984); stimulate discussion and provide a focus for students to discuss their activities; and provide a means for the teacher to assess what students have done.

Thus, microcomputers offer an intriguing arena in which to examine how visual and manipulative experiences can enhance children's learning in mathematics (Perl 1990). Rather than replacing work with real, tactile objects, how might computer manipulatives offer children valuable and distinctive learning opportunities to complement and extend their hands-on manipulative experiences?

Computer Beansticks

Over the past five years, Education Development Center, Inc. (EDC) has been exploring this notion of on-screen manipulatives across a variety of research and development activities. One of our initial forays in this area was a design

experiment employing the use of "computer beansticks," based on materials developed by Robert Wirtz and Curriculum Development Associates (1974). The prototype lessons we developed—utilizing computer software, actual manipulatives (real beans and sticks), and print-based activities—were focused on number patterns, grouping, and addition facts. The activities were designed to introduce young children to notions of grouping and counting-on as alternatives to simple one-by-one counting strategies for counting and addition.

Both the actual manipulatives and the software allowed children to construct and work with popsicle-type sticks on which they could arrange and affix different sets of beans. (See figure 1.) Given our base-ten number system, the emphasis was on grouping by five. By working with these materials, students begin to recognize or deduce, for example, that a beanstick contains seven beans, not by counting each bean one by one, but by counting-on from five, or by recognizing that five plus two equals seven.

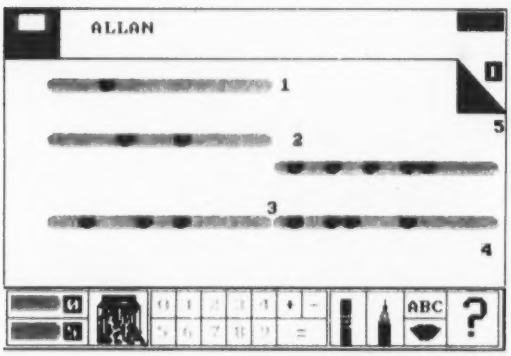


Figure 1

The student software contained two structured activities focusing on addition concerning sums of ten through twenty (teen facts), and an open-ended graphics tool resembling an electronic feltboard. Also available to teachers were several additional beanstick software activities to help them introduce and demonstrate concepts of grouping to their students.

In this paper I will be focusing on only the open-ended feltboard software, which offered an environment in which students could freely construct beanstick pictures. Using a mouse, children could drag onto the screen workspace a number of objects such as beans from a bean jar, beansticks (either a blank stick, or one already featuring one group of five beans), and mathematical symbols. They could also add text to the screen using the keyboard. (See figure 2.)

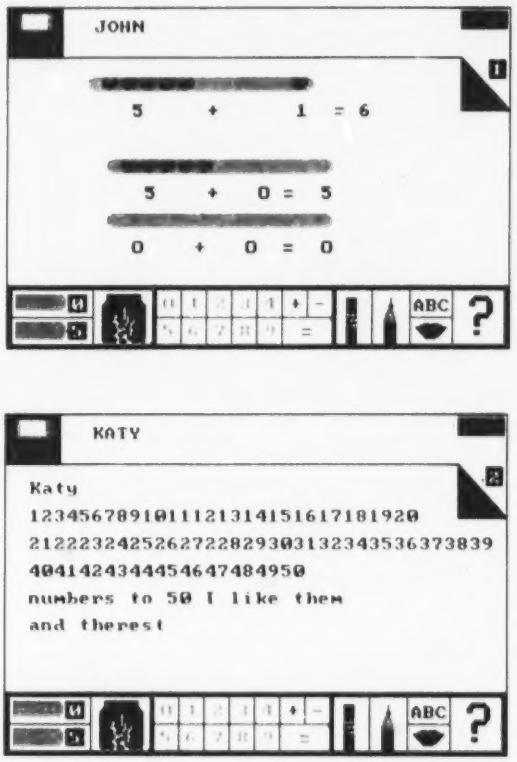


Figure 2

The Classroom Field Tests

The beanstick materials were tested with sixty-three children in kindergarten and first grade. Thirty-one of the children participated in pilot sessions testing early versions of these materials. In one pilot study, kindergarten and first-grade children were asked to work in pairs with the materials during a half-hour session and were observed and interviewed by a researcher. In a second pilot study, kindergarten children were introduced to the materials by their teacher

as part of a classroom activity involving the whole class, and were observed as they worked with the materials for approximately one and a half hours over the course of two mornings.

The remaining thirty-two children participated in a classroom field test and worked with the materials as part of a three-week summer program. In one classroom, there were eleven students who were to enter first grade the following fall, while in the other classroom there were twenty-one students about to enter second grade. Two experienced elementary school teachers participated in the study; each was responsible for teaching a classroom of students for nine morning sessions (three mornings a week for three weeks).

The sessions were organized much like a mathematics enrichment summer class. Approximately forty-five minutes each morning were devoted to the prototype beanstick materials, while the rest of the morning was organized around other mathematics activities not specifically related to grouping or addition about the teen numbers (for example, setting up a class store, building geometric sculptures out of toothpicks and gumdrops, listening to a story with a mathematics problem central to its plot) or other regular class activities (such as recess, snack time, and singing). Five computers (IBM PS/2 Model 30) were available in each classroom. Four were designated for student use, while the fifth doubled as both a teacher's station and a student's station. To enable children to work in pairs, two chairs were placed at each computer station.

A variety of measures were employed for the field test, including daily classroom observations, teacher and student interviews, teacher journals and written logs, and collections of student work.

Results

Classroom Management Issues

Ease of beanstick construction. Perhaps surprisingly, we found that children were able to handle and construct software beansticks with equal, and sometimes greater, control and facility, as compared to real beans and sticks. First, we observed that young children working with the real hands-on materials were faced with a formidable task. Children sometimes found the small, slippery beans difficult to place on the stick; a slight bump on the stick might send unglued beans rolling. Children had particular difficulty working with glue. They devoted considerable energy and attention to figuring out how to work with this fluid, messy material and sometimes were distracted from the central task of determining the number and arrangement of beans. In several cases, the glue took priority over the child's prior mathematical intentions: extra glue might pour out of the glue bottle, and the child would decide that she might as well add another bean to place on the extra drop.[2]

In contrast, after some initial learning to use the mouse during the first session with the computer software, almost all of the children easily grasped how the program operated. Using the mouse, they quickly became facile at clicking on bean and stick icons (located at the bottom of the screen), and dragging them to construct beansticks on the major area of the screen designated as the workspace.[3]

Interestingly, several children appeared to find it easier to express themselves through the software by dragging up the numbers displayed on the screen rather than by drawing them by hand using paper and pencil. In these early primary years, some children can correctly recognize different numerals yet have difficulty forming them by hand. For example, some young children are able to visually differentiate between the numerals 6 and 9, but will still interchange or blur the two forms when writing them. (A similar confusion sometimes arises with the numerals 5 and 2.) With the software, these children could simply drag numbers into place to express their mathematical ideas. In our interview, the kindergarten teacher reported of one child:

> Jody does not write numbers real comfortably; she does a lot of numbers backwards and is aware of it. So I think the fact that she was able to control the mouse and that the numbers were already written for her made it easier for her. . . . She performed better with the computer than she did with the paper.

Of course, not all children found the software to be a better method of working with numbers. A few of the children in our study, such as five-year-old Allan, had some problems with the mouse, although they were adept with a pencil. According to Allan's teacher, "He seems to focus better on the paper, because he has had a lot more experience with paper and pencil. My sense is that for Allan, familiarity is a real factor."[4]

Certain software design features seemed to contribute to the ease of use we observed. First, the beanstick graphics closely resembled the real beans and sticks to which children already had been introduced. The similarity forged a natural and clear connection between the two types of materials. Second, through formative testing of early versions of the software with children, we were able to fine-tune the user interface so that children could easily and effectively use the mouse to move, place, and neatly arrange sticks and beans. Some of our research also addressed which fonts and forms of numerals are more easily recognizable by children.[5] Third, our screen design provided a logical, uncluttered, and consistent use of icons: there was clearly an area at the bottom of the screen from which children got objects, such as beans from a bean jar, sticks, numbers, and addition and equal symbols. Similarly, there was clearly an area that was workspace, in which children constructed their beanstick creations.

Together, these design features seemed to contribute to a very natural and "like real life" process of constructing beansticks. For example, early on in our summer field test, we observed several pairs of children creating beansticks on the screen. After being informed by their teacher that it was time for them to finish up the activity before turning off their computer, they carefully placed all the beans, sticks and number symbols, one by one, back into the icon space where they had gotten them, much as if they were putting blocks away in the block corner.[6]

Ease of classroom implementation. The field test teachers reported that the software offered them an easily implementable way to offer children experience with manipulatives. As described above, the children found the beanstick software easy to use, often handling it with greater facility than real beans, glue, and sticks. Furthermore, one teacher specifically mentioned that the computer minimized some of the housekeeping chores that often accompany teachers' use of manipulatives:

> There's a whole other range of advantages, like beans on the screen don't go across the table onto the floor, and the sticks are always there on the screen. Less housekeeping.

The Fluid Integration of Objects and Symbols for Children's Collaborative Exploration

One of the insights gained through the field test experience was a clearer identification of the multiple ways an open-ended tool such as the electronic feltboard can be used in a classroom. Over the course of the three-week field test, teachers and researchers identified the mathematics graphics tool as useful in a number of different ways: 1) as a demonstration tool; 2) as a vehicle for students' independent and collaborative work; 3) as a recording device for work with hands-on manipulatives; and 4) as an informal assessment device. Each of these uses is described below.

Software as a demonstration tool. Both field test teachers usually began each morning with a whole-class demonstration and discussion, and used the software to provide an introduction to the mathematical concepts addressed that morning. The kindergarten teacher felt that the software's greater flexibility gave it distinct advantages over hands-on materials for teacher demonstrations and group instruction.

> With real materials, it is hard to hold up beansticks and talk to the class, making it hard to do demonstrations. One of the things the computer does real well is that I could easily do that on the screen, move the beans around, place the numbers next to the beans. It all made group instruction much easier than using the real beansticks. Yet it was very close to the real thing since you could move the beans.

Software as a flexible environment for children's independent and collaborative exploration and expression. While both field test teachers regarded the creation of real beansticks as an important component of their lessons, they did not believe that work with

hands-on materials necessarily needed to precede software experiences. On several occasions, the teachers mentioned that in some respects the software provided an easier, more flexible environment for exploring grouping than the construction of actual glued beansticks. Given the flexible nature of the software (in which beansticks were never permanently fixed), children could construct visual displays of different beansticks, yet continue to arrange and rearrange the beans as they saw fit.

In contrast to software requiring separate keyboard entry of numbers, the beanstick software's presentation of numbers and mathematical symbols as graphic objects readily available alongside beans and beansticks on the screen seemed to invite children's spontaneous integration of objects and symbols. Numbers were now "things to be used and acted upon," as opposed to an afterthought when working with manipulatives. We observed many instances in which children spontaneously used numbers to label their different beanstick creations. Alternatively, some children first placed a number next to a stick as if assigning it a goal, and then proceeded to place the appropriate number of beans to match the number.

The fluidity with which children integrated numbers and objects was evident in our classroom observations and often proved rich and involved, as illustrated in the following exchange between Dean and Ellen, two five-year-olds:

Dean and Ellen are working with a set of three beansticks their teacher has already placed on the screen as a place to begin. The sticks have 5, 7, and 9 beans, grouped as shown in figure 3.

Dean: I want to add a number — 7. *He Puts a 7 beside the 7 stick (figure 4).*

Ellen: I want to put more beans on the top stick. *She adds a bean, and then counts aloud.* 1, 2, 3, 4, 5, 6. *She then drags a 6 and puts it next to the stick (figure 5).*

Dean then places another bean on the top stick.

Ellen: You have to erase it. *She is referring to the number, which is now inappropriate.*

Dean then erases the 6 and places a 7 beside it (figure 6, page 8).

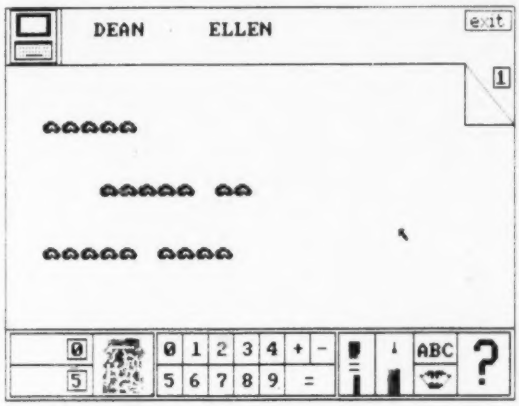


Figure 3

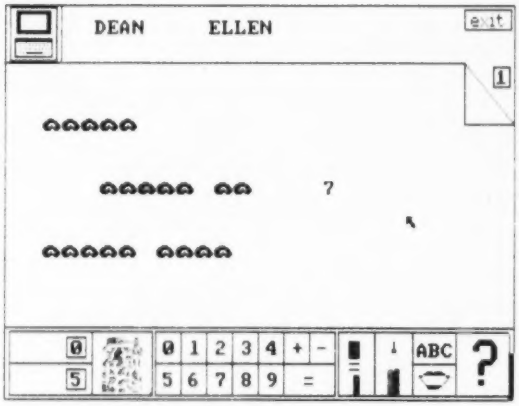


Figure 4

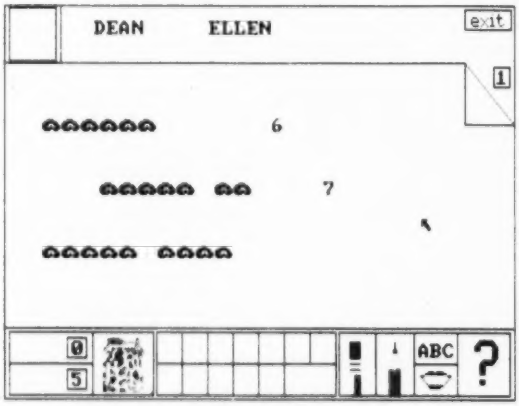


Figure 5

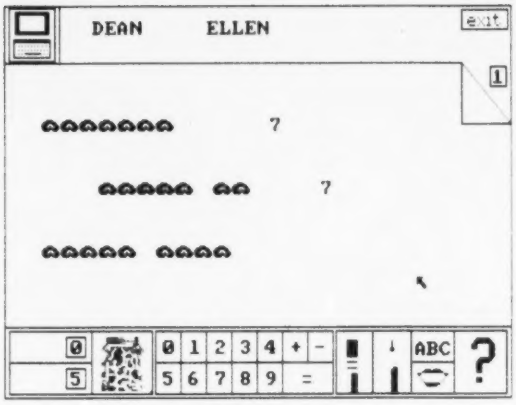


Figure 6

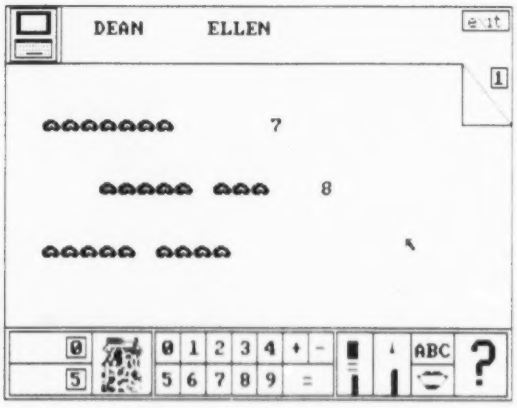


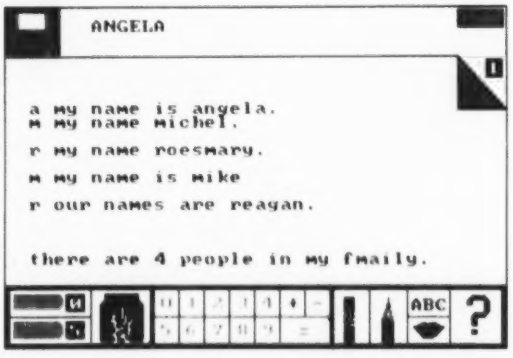
Figure 7

Ellen then erases the 7, gets a bean, and places in on the second stick. I want to put up a number. *She then counts to 8, using her fingers, and drags up an 8 (figure 7).*

This type of rich exchange between children working together at the computer was frequently overheard and observed in our field test classrooms. There is some evidence that computer software, through its structured and explicit user options and constrained screen space, encourages children to make more explicit their intentions and decisions when working in pairs at the computer, as compared to working together with the software's real three-dimensional counterparts.[7]

The software also allowed children to enter text as part of their beanstick constructions. This option was elected much less frequently, and was most commonly used simply as a text editor with which children wrote their names or comments. (See figure 8.) It should be noted that neither the prototype lessons, nor the field test teachers strongly emphasized the use of written text or encouraged children to incorporate written text and language into their beanstick activities. Children's creative use of language to express their mathematical experiences holds much promise (e.g., Kliman and Kleiman 1990; Van Den Brink 1987), but is commonly overlooked.

Software as a recording device. Towards the end of the field test, one of the teachers came up with the idea of integrating the software and manipulatives into a single activity. During the final days of the field test, she encouraged several children to explore how many different ways they could arrange a fixed number of


ANGELA
a my name is angela.
m my name michel.
r my name roesmary.
m my name is mike
r our names are reagan.
there are 4 people in my fmaily.

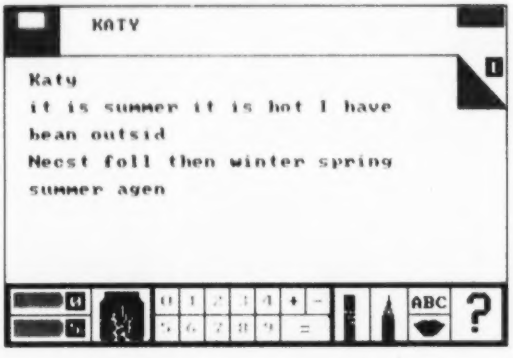


Figure 8

beans on two real sticks, and to use the software to make (and save) a picture of each different beanstick they constructed. Thus, the software was used as a recording device to document the rapid sequence of transformations and experimentation common in children's work with manipulatives which usually leaves no trace or visual trail for either students or teachers.

Software as an informal assessment tool. The software program's open-ended nature, allowing students' independent investigation and free expression, also provided an interesting mirror that reflected children's evolving notions of beansticks, grouping, and sums. As the summer field test progressed and the children participated in more structured activities focused on grouping and counting, we saw the emergence of spontanous grouping behavior reflected in the beansticks created during children's free play with the feltboard software. (See figure 9.) Thus, the software also provided a non-intrusive informal assessment tool with which teachers, and researchers, could guage children's assimilation of different mathematical concepts.

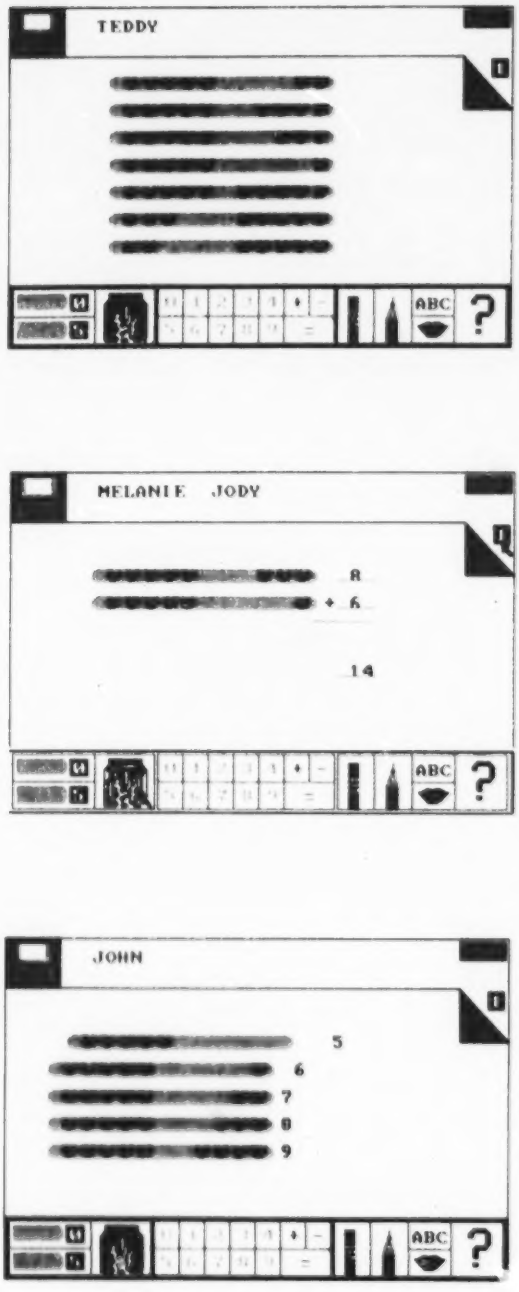


Figure 9

Conclusions

In summary, our research suggests that software can provide a valuable manipulative environment for young children's mathematical exploration, offering user control and flexibility comparable to or even greater than that offered by hands-on materials. By taking advantage of the computer as a "symbolic machine" capable of presenting objects, numbers, and words, software may encourage more frequent and spontaneous integration of objects and symbols by children and provide opportunities for them to stand back, comment, and reflect upon the manipulative products they are creating.

There are, however, a few caveats. First, work with real hands-on materials still appears important, and our findings should not be misconstrued to imply that software should replace experiences with real materials. In fact, both field test teachers relayed the importance of accompanying software-based activities with concrete experience.

Upon retrospection during her final interview, one teacher described how she would have implemented the activities differently to make an explicit connection between software and manipulatives.

> I think the connection between software and manipulatives should be introduced right at the beginning. On Day One (of the nine day field test) I probably would do it the same way (i.e., have children use the software only) because that was when the kids really needed practice with the mouse: just kind of pulling the numbers out, moving things around the screen. But on the second day, I would have them work with the beansticks on the table in front of the computer. I'd have a few blank sticks and little dish of beans and have them make a beanstick without glue, or then they could make one on the screen to match the one on the table, or they could do it in the other order. So if I asked them to build five beansticks on the screen, I'd want to see a set of matching beansticks down on the table.

Teachers did not feel, however, that it was necessary for hands-on experiences to precede software experiences. On several occasions, teachers mentioned that in some respects the software offered an easier "manipulative environment" for exploring grouping than the construction of actual glued beansticks. For example, one teacher had children explore multiple ways to do groupings with the computer, but wanted them to focus only on groupings by five by the time they were going to glue down the beans to make beansticks.

> I like the kids to do the beanstick software first, and then move to making their own beansticks with glue. I want them to visually see how beansticks could be grouped so they won't have to do a lot of work when they make their own (using real beans and glue).

However, as noted earlier, in many classrooms children do not use real manipulatives because teachers find them too difficult or cumbersome to manage. Thus, on-screen manipulatives could provide some children with a visual, manipulative approach to mathematics that may be otherwise lacking in their school. One area of research to be pursued is the extent to which children's handling of real manipulatives is critical to the educational benefits of software manipulative experiences.

Second, it seems clear that not all concrete manipulatives can be easily or appropriately converted into software objects, and that our beanstick manipulatives may have lent themselves particularly well to software conversion. We suspect that manipulatives that stress their three-dimensionality, such as cubes that are stacked and rotated, may not translate particularly well into software and would be difficult for young children to work with on the screen. Similarly, manipulative experiences that rely heavily on relationships or movement through three-dimensional space, or highly kinetic sensations such as weight and force, would probably prove challenging in a software world.

Since this prototype work was conducted, we have created several other types of exploratory computer graphic environments for young children's mathematical problem posing, in the domains of measurement, time, and money.[8] For example, with one program children are able to drag various coin combinations onto the screen, and hear, through digitized speech, the total cost of the set. With another program, children can move the hands on a clock and hear the corresponding time, or move graphic objects on the screen and measure them with rulers or non-standard units. Classroom field tests of these materials have yielded encouraging results as well.

Our work suggests that microcomputers can offer a powerful new arena for researchers and materials developers alike to examine ways in which visual and manipulative experiences can facilitate children's learning in mathematics. We hope our initial, exploratory work points to some promising directions for further work in research and software design.

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Notes

1. For such an activity, see *Exploring Measurement, Time and Money, Level 1*, 1989-1990.

2. Of course, adjustments can be made regarding what types of manipulatives teachers choose to use with children. One of the field test teachers elected

to have children also construct grouped sticks by placing colored dot stickers on a stick, thereby bypassing the problem young children have with glue.

3. Our decision to use the mouse as the input device was based on some earlier research we conducted investigating the relative merits of touch screens and mouse devices (Char 1990). At first glance, one would predict that the touch screen, with its one-to-one mapping of gesture to graphic object, would be a preferable method. However, we quickly discovered that the touch screen posed considerable hurdles to child users. For one thing, it needed to be calibrated to take account of the user's vantage point and angle of gesture, which was problematic with software designed for use by more than one child at the same time. Moreover, as one might expect, young children are active, often shifting sitting positions and moving from sitting to standing. Thus, the calibrated gestural angle is soon obsolete, even for one user.

Furthermore, we discovered that children spontaneously touch the screen in the process of counting objects and referring to items on the screen. Thus, it was likely that a child would point to the screen not so much to indicate her selection at some decision point, but to help with the process of arriving at a solution (for example, pointing to beans on the stick, in order to count them). Such gestures "in process" would mistakenly be read by the computer as input, and would inadvertently set off the program's response. For these reasons, we decided the mouse was the preferable input device.

4. Given the constraints of the three-week field test, we did not have the opportunity to examine how someone like Allan would have done over an extended period of time. It would have been interesting to study whether with increased exposure to and familiarity with the software, Allan would have continued to have difficulty controlling the mouse.

5. For example, some of our early research closely studied how well children could control the cursor using the mouse in their initial beanstick constructions in order to help us define how large the "hot spot" should be for a bean. That is, we needed to provide children with a little leeway so that they did not have to place the cursor precisely on top of a small bean icon, yet not permit the area to be so large that children would move an object when they didn't even think the cursor was near it. Other interface issues examined such details as the presentation of numeral fonts. One early version of the software presented the number 0 as the typical computer-generated zero with a diagonal slash through the middle (Ø). In testing, children mistook this numeral for an 8.

6. A few sessions later, the children learned that the broom icon helped clear the screen, and they then utilized that option to perform the clear function.

7. In the study by Forman (1984), the tendency of children to announce beforehand the actions they wish to perform on the computer was observed when he compared preschool children's symbolic play with computer animation software and real three-dimensional toy props.

8. See *Exploring Measurement, Time, and Money*, 1989-1990.

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